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Impact of habitat change on abundance of Buff-breasted Sandpiper (*Calidris subruficollis*) and other Nearctic shorebirds in Bahía de Asunción, Paraguay

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ABSTRACT—We present an assessment of the impact of human-induced habitat change on the abundance of Nearctic shorebirds at Bahía de Asunción in Paraguay. Regular surveys since 2000 showed that the study area is an important stopover site for migratory shorebirds using the Midcontinent Flyway and led to its designation as a Western Hemisphere Shorebird Reserve Network site of Regional Importance and as a national protected area due to holding more than 1% of the global population of Buff-breasted Sandpiper (*Calidris subruficollis*). In late 2010, the development of a bay-side road (“Costanera”) altered the shorebird habitat in Bahía de Asunción through dredging to build an embankment for the road. Of the 100 ha of habitat primarily used by shorebirds, over 50% was converted to deep water and steep shorelines by the dredging. Pre- and post-dredging surveys showed a significant reduction in abundance for most of the commonly recorded species. Single-day high counts of the Buff-breasted Sandpiper decreased by a factor of 4. Although plans for habitat restoration exist, to date there has been only limited implementation. Without a concerted effort to restore and actively manage shorebird habitats over time, the Bahía de Asunción is destined to be lost as a key stopover site for migratory shorebirds. *Received 22 June 2023. Accepted 16 August 2024.*

Key words: dredging, habitat loss, migration, Scolopacidae, stopover, WHSRN.

Impacto del cambio del hábitat en la abundancia del playerito canela (*Calidris subruficollis*) y otras aves playeras del Neártico en la Bahía de Asunción, Paraguay

RESUMEN (Spanish)—Presentamos una evaluación del impacto del cambio de hábitat causado por el humano sobre la abundancia de aves playeras neárticas en Bahía de Asunción, Paraguay. Censos regulares desde el año 2000 mostraron que el área de estudio es un importante sitio de parada para las aves playeras migratorias que utilizan la Ruta Migratoria “Mid-Continental” y llevó a su designación como sitio de Importancia Regional de la Red Hemisférica de Reservas para Aves Playeras y como área protegida nacional debido a que alberga más del 1% de la población mundial del playerito canela (*Calidris subruficollis*). A finales de 2010, el desarrollo de una costanera junto a la bahía alteró el hábitat de las aves playeras en Bahía de Asunción mediante el dragado para construir un terraplén para una carretera. De las 100 ha de hábitat utilizado principalmente por las aves playeras, más del 50% se convirtieron en aguas profundas y costas acantiladas debido al dragado. Los censos previos y posteriores al dragado mostraron una reducción significativa de la abundancia de la mayoría de las especies comúnmente registradas. Los conteos máximos de un solo día del playerito canela se redujeron 4 veces. Aunque existen planes de restauración del hábitat, hasta la fecha su aplicación ha sido limitada. Sin un esfuerzo concertado para restaurar y gestionar activamente los hábitats de las aves playeras a lo largo del tiempo, la Bahía de Asunción está destinada a perderse como lugar de parada clave para las aves playeras migratorias.

Palabras clave: dragado, migración, pérdida de hábitat, RHRAP, Scolopacidae, sitio de parada.

Many North American–breeding (“Nearctic”) shorebirds are long-distance migrants that depend on a select number of stopover sites along their migration routes to feed and rest. These stopover sites form a chain that connect breeding and non-breeding areas and are as vital for their survival as sites where they breed or spend the nonbreeding season (Hunter et al. 1991, Harrington and Perry 1995, Sheehy et al. 2011, Linscott and Senner 2021, Wang et al. 2022).

Moore et al. (1995) considered that habitat loss in stopover sites can result in lower resource availability and consequently reduce an individual’s condition to continue its journey to the next stopover site or wintering grounds. If this happens to many individuals it can result in population declines. Unfortunately, the effect of reduced quality or direct loss of habitat used by populations during migration has received little attention (Fernández and Lank 2008), but a clear and often-cited example of population decline of shorebird species in the Yellow Sea (China) due to human-induced habitat reduction shows that this effect can be significant (Studds et al. 2017). Recognition of the importance of conserving key sites for shorebirds in the Americas resulted in the creation of the Western Hemisphere Shorebird Reserve Network (WHSRN; further information in Supplemental Table S1).

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The Bahía de Asunción (Asunción Bay) is a WHSRN site of Regional Importance declared in 2008 on the basis of holding more than 1% of the global population of the Buff-breasted Sandpiper (*Calidris subruficollis*). The Buff-breasted Sandpiper breeds along Arctic coasts in easternmost Russia, Alaska, and Canada and spends the nonbreeding season in South America in the Pampas of Argentina, Uruguay, and southern Brazil (Lanctot et al. 2010). It migrates primarily through the interior of Canada and the United States, across the Gulf of Mexico, and through the center of South America using the Central Amazonian/Pantanal flyway as described by Antas (1983) and documented with tracking data (Lanctot et al. 2016). The species is considered Near Threatened at the global level (Birdlife International 2020) due to the significant population declines it has suffered. These declines were mostly a result of historical hunting, and currently the main threat to the species is considered to be loss of habitat (Lanctot et al. 2010). Due to the species' poor conservation status, it is considered a focus for the Midcontinent Shorebird Conservation Initiative, for which a strategic framework is currently being developed.

In Paraguay the Buff-breasted Sandpiper is a regular passage migrant, mostly recorded during southbound migration (mid-Aug to late Nov), but uncommon to rare during northbound migration (mid-Mar to early May) and boreal winter months (Smith and Clay forthcoming). Most records of this species are from the Paraguay River valley, where birds are found in areas of short grass on sandbanks and river islands, but also in rice fields within the watershed (Lesterhuis and Cartes 2008, Lanctot et al. 2010). Limited observations and tracking data also suggest that the species uses more isolated wetlands and adjacent shortgrass habitat in the Dry Chaco (primarily a xeric thornscrub ecoregion).

The Bahía de Asunción is also an important stopover site for several other species of shorebird. A total of 20 Nearctic shorebird species have been reported to date and showed a significant correlation during southbound migration (Aug–Dec), with the highest abundances of shorebirds occurring when water level was low, with few to no shorebirds present during periods of

high water levels (Hayes and Fox 1991, Lesterhuis 2015). A key determinant of shorebird use of the site appears to be water level and its fluctuations. Besides the Buff-breasted Sandpiper, other regularly occurring species include American Golden Plover (*Pluvialis dominica*), Lesser Yellowlegs (*Tringa flavipes*), White-rumped Sandpiper (*C. fuscicollis*), and Pectoral Sandpiper (*C. melanotos*; Hayes and Fox 1991, Lesterhuis and Clay 2001, Lesterhuis 2015).

In late 2010, the development of a major access road to the center of Asunción along the edge of the bay (the “Costanera”) had a significant impact on habitats. An embankment was built for the road, directly replacing wetland areas and changing waterflows into the bay. Furthermore, sand for the embankment was dredged from the bay, destroying significant areas of sand and mudflats and greatly increasing the depth of parts of the bay. Here we assess the habitat changes due to the dredging activities and compare data for Buff-breasted Sandpiper and other Nearctic shorebirds from before and after the dredging to evaluate the impacts and report on the current status of this important stopover site within the Midcontinent Flyway.

Methods

Study site

Bahía de Asunción (25°15'49"S, 57°37'47"W) is a relatively small bay of 522 ha located along the northern outskirts of Asunción, the capital of Paraguay (Fig. 1). The bay is separated from the Paraguay River by the Banco San Miguel, a narrow peninsula of low-lying land, and its water level is regulated by the river's flood cycle, typically with high water levels in the austral autumn and winter, and low levels during the austral spring and summer (Hayes and Fox 1991, Lesterhuis 2015). The Bahía de Asunción contains a variety of habitats, including bodies of freshwater, mudflats and sandy beaches, marsh vegetation, seasonal inundated grassland, and patches of scrub forest (Guyra Paraguay 2008, Lesterhuis 2015). As a result of seasonal water level fluctuations, the width and depth of the bay varies greatly, affecting the availability of habitat.



Figure 1. Bahía de Asunción in October 2010, a few weeks prior to the initiation of dredging activities. The oval depicts the main survey area for this study, including the main habitat used by the Buff-breasted Sandpiper. ©Google Earth.

The eastern and southern shores of the bay are a densely populated municipality (Hayes and Fox 1991). Residents on the south shore of the bay are now separated from the bay by the Costanera. Fewer people live on the Banco San Miguel, but the population has been increasing in recent years, especially since construction of the Costanera, which has facilitated access. The main activities carried out in the bay include fishing, hunting, and small-scale agriculture on the Banco San Miguel (Hayes and Fox 1991, Lesterhuis 2015). Historically, access to the bay was difficult, and recreational activities were limited to water sports (primarily rowing). However, the Costanera provides ready access to the south side of the bay and is now the primary area for outdoor recreation within Asunción. Garbage is a serious problem within the Bahía de Asunción and is found throughout the area. There are 2 main sources, clandestine tips on the Banco de San Miguel (with shacks built on the infilled wetlands) and in the low-lying community located between the city center and the Costanera, and garbage washed out into the bay from the city center during heavy rains.

The Bahía de Asunción was declared a reserve by law N° 2715 in 2005, named “Ecological Reserve of Banco San Miguel and Bahía de Asunción,” and is an Important Bird Area (IBA). The Reserve is the first case of co-management between the Municipality of Asunción and the Ministry of Environment (MADES)—the municipality owns the Banco San Miguel Peninsula, while the Ministry is responsible for the water body (Guyra Paraguay 2008).

Habitat change analysis

To assess changes in habitat we generated classifications (maps) of land use changes over time. We quantified land cover change in the Bahía de Asunción between 2 periods: 1999–2003 and 2014–2017 (i.e., covering a period before and after dredging). For this we used the Remap app (Murray et al. 2018) that uses Landsat image mosaics and Random Forest Classification, utilizing Google Earth Engine capacity. Remaps uses up to 13 publicly available predictor datasets. We used the following predictors: normalized difference vegetation index (NDVI), normalized difference water index

(NDWI), normalized difference blue green (BG), blue band (Blue), green band (Green), red band (Red), near infrared band (NIR), elevation, and slope. We first produced a classification map of the past (i.e., year 2003) by developing a training set for each of 4 differentiable land cover units: lowlands grasslands ($n = 22$ training points), dry grasslands ($n = 30$ training points), water (32 training points), and sand (45 training points). The number of training points varied according to habitat type area in the period before dredging. Then, using the same training set of points, we projected those land cover units to the time after dredging (i.e., year 2017). The outcome of this analysis is 2 maps with the distribution of the land use units that allow us to compare areas before and after dredging. Of special interest were areas of lowland grasslands, the main habitat used by the Buff-breasted Sandpiper. The error rate per classification map was obtained by calculating the percentage of training points that were incorrectly classified by the model that was trained with all of the training data.

Field data

The surveys were carried out following the International Shorebird Survey (ISS) protocol, which involves the implementation of regular surveys during migration in a defined area and counting all shorebirds observed (Howe et al. 1989, Manomet 2024). Our study area comprised approximately 100 ha of which approximately half was habitat frequently used by the Buff-breasted Sandpiper (Fig. 1). During each visit, we surveyed the whole study area, walking along the coast and short grassland areas, keeping a responsible distance to not flush observed shorebirds. Due to high visibility in the area, detectability was not considered as a constraint to find birds. Areas with higher vegetation were walked through to look for Upland Sandpiper (*Bartramia longicauda*). We conducted a total of 138 surveys during the southbound migration season (Aug–Dec) of 2000–2004 (pre-dredge) and 2011–2016 (post-dredge). Both study periods span 5 years, although no data were available for 2014. A total of 88 surveys were carried out during the pre-dredging period (2000–2004) and 55 were carried out after

the dredging. Most of the surveys (58%) were carried out in September and October. All surveys were conducted on foot, primarily starting at the main principal access point to the bay. Surveys were mostly carried out in the morning and took on average 2.5 h. All shorebird species observed were identified and counted using binoculars (10×42) and occasionally a spotting scope ($20\text{--}60\times$).

Statistical analyses

Pre- and post-dredging survey data was analyzed for abundance of Buff-breasted Sandpiper and 9 other common Nearctic shorebirds. Each count on a different day was our sampling unit. A species was considered as “common” when it had at least 30% presence during either survey period. Those species recorded during the study period, but not reaching that threshold, were not considered for the analysis. Data on resident species was not used for this analysis.

The effect of dredging the area on different Nearctic migrant shorebirds species at the site was assessed through fitting a generalized linear model (GLM). The response variable was count data on each day for each species. Explanatory variables were pre- and post-dredge periods (binary variable), species identity, and the interaction terms between these 2 factorial variables. The interaction term allowed us to assess if dredging differentially affected shorebird species counts and estimate the expected abundance of each species before and after dredging. We used negative binomial distribution probability to model abundance as Poisson showed over-dispersion.

Model adequacy was assessed by visually inspecting graphical residuals. All analyses were conducted with R software (R Core Team 2021). The following R packages were used to model and represent the results: *glmmTMB* (Brooks et al. 2017), *MASS* (Venables and Ripley 2002), *ggeffects* (Lüdtke 2018), and *ggplot2* (Wickham 2016).

Results

Habitat change

The classification maps generated to analyze land cover change over a 15 year period showed important differences between pre- and post-dredging (Fig. 2). Pre-dredging, an area of 103 ha was

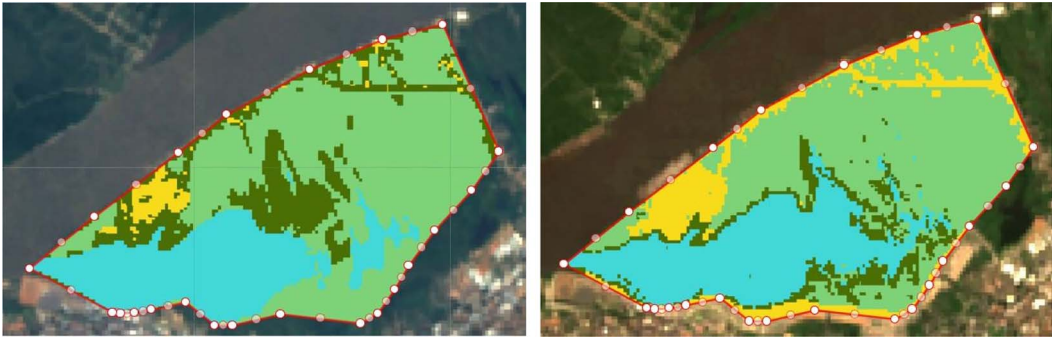


Figure 2. Habitat classification of Bahía de Asunción, Paraguay, from pre-dredging (left map) and post-dredging (right map). Legend: light green = high grassland/shrub; blue = water; yellow = sand; dark green = lowland (short) grassland.

classified as lowland grasslands, while post-dredging, this habitat type was reduced to 58 ha (Table 1). The error rate for the pre-dredge model was 12.4% and 3.8% for the post-dredge model.

Shorebird diversity and abundance

A total of 18 Nearctic shorebirds were recorded, of which all were recorded during the pre-dredging study period and 15 during the post-dredging study period. Species not recorded during the post-dredging study period included Ruddy Turnstone (*Arenaria interpres*), Red Knot (*C. canutus*), and Dunlin (*C. alpina*). All are considered rare or accidental species at the study site (AJL and RPC, unpubl. data). Two additional species, Least Sandpiper (*C. minutilla*) and Semipalmated Plover (*Charadrius semipalmatus*), were also recorded during the current study period (Lesterhuis and Clay 2011; AJL and RPC, unpubl. data) but outside the southbound migration months considered for the analysis.

Highest single-day counts of Buff-breasted Sandpiper were 250 individuals on 11 September 2001, 140 on 28 October 2000, and 102 on 13

October 2000. All these counts were made during the pre-dredge study period. During the post-dredge study period the highest single day counts were 37 individuals on 15 December 2011 and 30 on 5 September 2013. In 2015 and 2016 single-day high counts did not surpass 10 individuals. The highest single-day counts of other Nearctic shorebird species that surpass 100 individuals are summarized in Supplemental Table S2.

Based on observation rate (presence during 30% or more counts in the study period), the 10 most regularly observed species during the pre-dredging period were also the most regular during the post-dredging period (Supplemental Table S2). No species was significantly more common during the post-dredging period.

Pre- and post-dredge variation

A significant difference in the abundance of the Buff-breasted Sandpiper was noted when comparing pre- and post-dredge data, with single-day high counts decreasing 4 times ($Z = -2.45$, $P < 0.01$; Table 2). The fitted GML model showed a higher abundance of the Buff-breasted Sandpiper

Table 1. Buff-breasted Sandpiper (*Calidris subruficollis*) habitat change in Bahía de Asunción, Paraguay. Results of the generated habitat classification maps using Remap app. Habitat reduced in coverage after dredging is indicated with “-” and habitat increased in coverage after dredging is indicated with “+”.

Habitat type	Pre-dredge area (ha)	Post-dredge area (ha)	Change in habitat (%)
High grasslands	317	293	-7.6
Water	152	160	+8.4
Sand	19	80	+321
Lowland grasslands	103	58	-43.7

Table 2. Shorebird habitat change before and after the construction of the Costanera in Bahía de Asunción, Paraguay. GLM estimated coefficients corresponding to the interaction term between Period (Pre- and Post-dredge) and Species (shorebird species identity). When Post-dredge: Species term is negative and statistically significant, it means a negative impact of dredge on the species.

Model term	Estimate	Standard error	Z value	Pr(> z)
Post-dredge: White-rumped Sandpiper (<i>Calidris fuscicollis</i>)	-1.0283	0.5062	-2.0314	0.0422*
Post-dredge: Stilt Sandpiper (<i>Calidris himantopus</i>)	-1.6085	0.5193	-3.0977	0.0020**
Post-dredge: Pectoral Sandpiper (<i>Calidris melanotos</i>)	-1.1931	0.5061	-2.3576	0.0184
Post-dredge: Buff-breasted Sandpiper (<i>Calidris subruficollis</i>)	-1.2483	0.5099	-2.4482	0.0144*
Post-dredge: Wilson's Phalarope (<i>Phalaropus tricolor</i>)	0.8299	0.5098	1.62788	0.1036
Post-dredge: American Golden Plover (<i>Pluvialis dominica</i>)	-0.5454	0.5080	-1.0735	0.2830
Post-dredge: Lesser Yellowlegs (<i>Tringa flavipes</i>)	-1.4574	0.5082	-2.8681	0.0041**
Post-dredge: Greater Yellowlegs (<i>Tringa melanoleuca</i>)	-0.1032	0.5331	-0.1936	0.8465
Post-dredge: Solitary Sandpiper (<i>Tringa solitaria</i>)	0.4285	0.5217	0.82141	0.4114

during the pre-dredging period, in comparison to the post-dredging period (Fig. 3).

An interaction effect of Period*Species variables of species counts was detected, which means that the period (pre- or post-dredge) affected the counts of species, though depending on species identity (Table 2). Most common species showed declining counts post-dredge (Fig. 3), but the rate of this effect was different among species. A very marked difference in abundance was observed for the White-rumped Sandpiper, Pectoral Sandpiper, and Lesser Yellowlegs, whereas for several other species the difference between the pre- and post-dredging study period was

not significant (Fig. 3, Table 2). For example, the Upland Sandpiper, Solitary Sandpiper (*T. solitaria*), Wilson's Phalarope (*Phalaropus tricolor*), and Greater Yellowlegs (*T. melanoleuca*) showed no significant variation between pre- and post-dredging. Differences in pre- and post-dredging abundance of American Golden Plover were also significant.

Discussion

Stopover sites are a critical link in the annual cycle of migratory birds and any alterations to such sites can have a major impact on the fitness

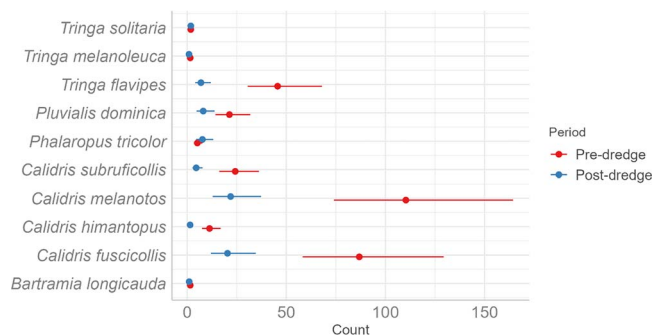


Figure 3. Abundance of the Buff-breasted Sandpiper and other common Nearctic shorebirds Pre-dredge and Post-dredge in Bahía de Asunción, Paraguay.

of populations and trigger declining trends. In this work, we found that the dredging of the Bahía de Asunción, started in late 2010 to create an embankment for an access road to the city center, had a visible and significant impact on the abundance of the Buff-breasted Sandpiper and other shorebird species using the area during south-bound migration. Our results align with other works that showed how habitat changes in stop-over sites decreased shorebird population abundance (Baker et al. 2004, Wang et al. 2022).

Human intervention, like habitat conversion or exploitation, can result in a variety of changes affecting a species, including changes like a decrease in the availability of food and reduction in available habitat and time for feeding (Fernández and Lank 2008). A good example of the impact of human influence on shorebird populations is the steep and rapid population decline of the Red Knot as a result of a significantly reduced availability of horseshoe crab eggs at Delaware Bay due to overharvesting (Baker et al. 2004). In our work, we detected a rapid shorebird abundance decline as a consequence of human induced increase in water depth (due to dredging), which might prevent shorebird access to the preferred substrate to feed on invertebrates (Schaffer-Smith et al. 2018).

Among the species for which we detected an abundance decline, Buff-breasted Sandpiper stands out for its global conservation concern. It is known that the species' declining population is mostly affected by habitat conversion (Lanctot et al. 2002), especially the loss of short-grass habitat the species uses during migration and on winter grounds (Lanctot et al. 2010, Aldabe et al. 2019). The analysis using habitat classification maps from pre- and post-dredging showed that over 50% of foraging habitat of all shorebirds was lost through conversion into deep water and steep shorelines, unsuitable for shorebirds.

Habitat loss was even more severe for Buff-breasted Sandpiper, with 65% converted. These percentage loss figures correspond to the direct loss through habitat conversion. Remaining areas of shorebird habitat have been degraded as a result of increased desiccation (due to changed water levels because of the dredging) and the expansion of pioneer vegetation such as jukeri

(*Mimosa* sp.). The latter is a shrub that rapidly invades open areas as the soil dries and is classified among the global top 100 invasive species in the region (Lowe et al. 2000), though it is native. Humid short-grass areas that were suitable for Buff-breasted Sandpipers to forage on have been covered by these taller shrubs, and open areas are now limited to just a few very sandy patches of soil. Thus, most of the approximately 35% original suitable habitat for Buff-breasted Sandpiper not destroyed by the dredging is also no longer suitable for the species. As a result, single-day high counts of the Buff-breasted Sandpiper dropped noticeably. Whereas during the pre-dredging period, the mean count was 24.3 individuals, during the post-dredging period this mean count dropped to 4.6 individuals (Supplemental Table S2). In addition, the likelihood of seeing a Buff-breasted Sandpiper was much lower, with an observation rate of about 40% after dredging versus nearly 70% during pre-dredging (Supplemental Table S2).

Similar changes in numbers and observation rates were found for most of the other common species such as Lesser Yellowlegs, White-rumped Sandpiper, and Pectoral Sandpiper, species that were very common in the Bahía de Asunción pre-dredging, but which had significantly lower counts after dredging. This is presumably due to an absence of virtually any shallow coastal areas which these species prefer for foraging (O'Brian et al. 2006).

There were a few exceptions to the observed pattern of declines in abundance. Upland Sandpiper favors drier areas with taller vegetation, and their numbers did not change much comparing pre- and post-dredging counts. Similarly, the numbers of the Solitary Sandpiper did not change significantly. For Solitary Sandpiper this is presumably because it is a species that favors small ponds and streams (O'Brian et al. 2006) that are found throughout the area and was only rarely recorded along the main shoreline. Thus, its habitat was less affected by the dredging. The slight increase of the Wilson's Phalarope is surprising as this species is also in part dependent on shallow coastal areas; however, it also forages on

open water which might have resulted in some flocks still being able to forage in the bay.

Whether the habitat modifications in Bahía de Asunción impacted survival of the Buff-breasted Sandpiper or any of the other species that showed significant declines in abundance is not clear and deserves further studies in other sites along the migratory route, but it goes beyond saying that when habitat is lost, birds need to find an alternative in order to be able to feed and rest. If a site is being negatively affected and habitat is destroyed or reduced then it is likely that other sites somewhere in the region will show an increased density (Sutherland 1998, Fernández and Lank 2008). This increase might be resulting in higher mortality as birds might face more stress or reduced food intake as a consequence of competition. However, there is no information on any alternative sites in the surroundings of Bahía de Asunción that the Buff-breasted Sandpiper and other shorebirds could rely on. In fact, based on available data (see Lanctot et al. [2010, 2016]), Bahía de Asunción could be considered the last key stopover site for Buff-breasted Sandpipers prior to reaching their final wintering grounds farther south along the coast of southern Brazil (Rio Grande do Sul state). Three adults banded at Bahía de Asunción in mid-September 2004 were later resighted at Lagoa do Peixe National Park in southern Brazil in early November and from October 2004 to January 2005 (Lanctot et al. 2010). An individual equipped with a light-level logger in 2012 by Lanctot et al. (2016) also stopped over in Bahía de Asunción and then continued to the coast of Lagoa do Peixe National Park. This National Park in Brazil lies approximately 1,000 km southeast of Bahía de Asunción; if the species would have to try to get there without having the opportunity to refuel and rest at Bahía de Asunción, its fitness might be severely impacted.

Importance of Bahía de Asunción

Studies on shorebirds in Bahía de Asunción have shown the site to be an important stopover site for Nearctic shorebirds. Hayes and Fox (1991) recorded a total of 15 species of which 10 were considered regularly occurring species, including

American Golden Plover, Lesser Yellowlegs, White-rumped and Pectoral sandpiper, Wilson's Phalarope, and Buff-breasted Sandpiper. These species were also the most frequently recorded by Lesterhuis and Clay (2001) during surveys in 2000–2001. However, average total counts of southbound migrant shorebirds were significantly higher during the surveys conducted by Lesterhuis and Clay (2001) than during those of Hayes and Fox (1991). Lesterhuis and Clay (2001) estimated that a minimum of 10,000 shorebirds used the bay during southbound migration in 2000, highlighting it as an important stopover site. The pre-dredging survey data reported here were the basis for designating the Bahía de Asunción as an IBA, WHSRN site, and a protected area. Based on current data, Bahía de Asunción would not qualify as a WHSRN site of Regional Importance. Conservation efforts must be directed toward recovering habitat in order to make sure the area can maintain its recognized status at the international level.

Future of Bahía de Asunción

This study documents a significant loss of shorebird habitat in the Bahía de Asunción, particularly for Buff-breasted Sandpiper, the species for which the site has been internationally recognized as important and one of the primary justifications for its declaration as a protected area (ecological reserve). Dredging for the construction of the Costanera road had an immediate direct impact through conversion of habitat. But degradation of the remaining shorebird habitat, especially for Buff-breasted Sandpiper, continues because of ongoing desiccation and expansion of an invasive shrub. Initial efforts to remove the *Mimosa* shrub from key areas were successful but have faltered in recent years due to the need for annual control/removal, exacerbated by atypically low water levels in recent years (limiting the extent of flooding).

Plans to restore both grassland and mudflat habitats and ongoing control of the *Mimosa* shrub exist, developed by Guyra Paraguay (BirdLife International in Paraguay), the WHSRN Executive Office and Manomet, and the Ministry of Public Works (Ministerio de Obras Públicas y Comunicaciones, MOPC). However, their implementation has been delayed pending approval of the management plan

for the reserve by MADES and the Municipality of Asunción. The management plan was recently approved but the MOPC's project has now closed. However, a new opportunity to restore key shorebird habitats in the bay may arise through the soon to be implemented "Asunción Urban Riverfront Resilience Project" financed by the International Bank for Reconstruction and Development (part of the World Bank group). Without a concerted effort to restore and actively manage shorebird habitats over time, the Bahía de Asunción seems destined to be lost as a key stopover site for migratory shorebirds.

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